# How to bring compute intensive C++ based apps to Android

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# Outline

1. Lets get started
   - Motivation – Why native code on Android?
   - Introduction – About the TiGL App for aircraft design at DLR

2. Hacking
   - Preparing Native App Development
   - Compiling and patching 3rd party libraries
   - Using JNI to communicate between Java and C/C++

3. Building
   - Integrate NDK build into Gradle

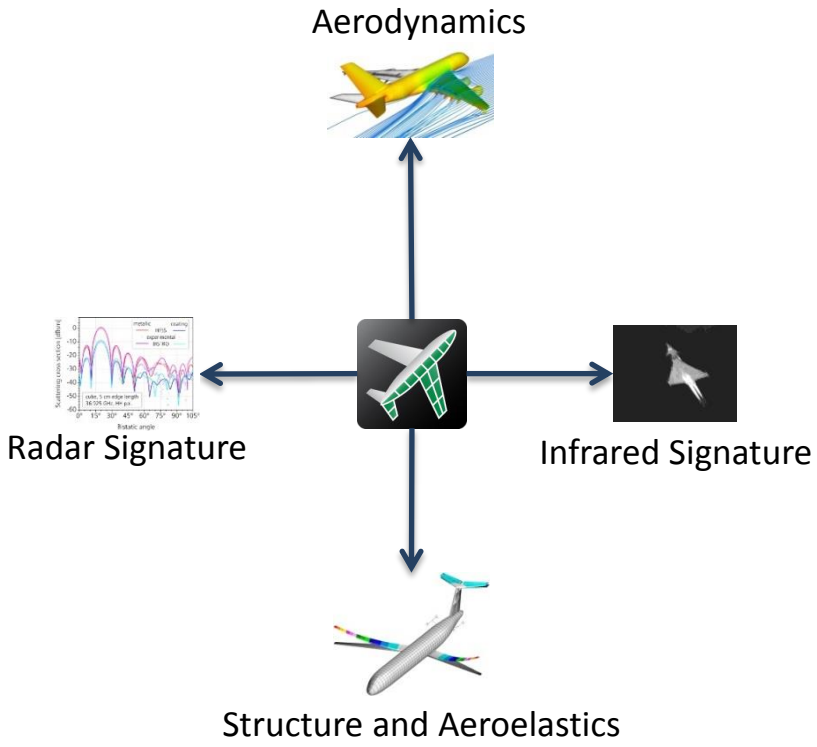
4. Testing / Running
   - Using the Android Emulator efficiently
   - Debugging with ndk-gdb and Eclipse

# Motivation – Why native code?

- Rewrite of large and tested codebase to Java not reasonable
  - Introduces new errors
  - Code depends on other 3rd party libraries without Java counterpart
  - Too time consuming
- Many numerical algorithms implemented in C or Fortran
- C and Fortran compilers produce highly optimized machine code
- On the other hand:
  - Native code is harder to debug
  - Must be ported (may contain platform specific code)

# About the TiGL project at DLR

- Central geometry viewer and library used by many simulation tools in DLR for aircraft design
- Written in C++, large tested code base
- Uses other Open Source Software:
  - CAD kernel OpenCASCADE
  - 3D engine OpenSceneGraph
- Multiplatform – Win, Linux, OS X, and Android
- Open Source , Apache 2.0

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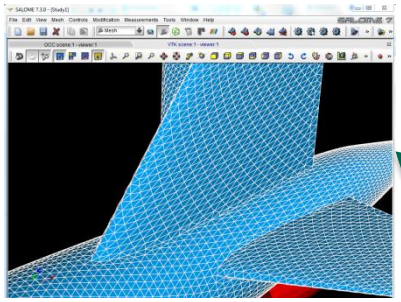
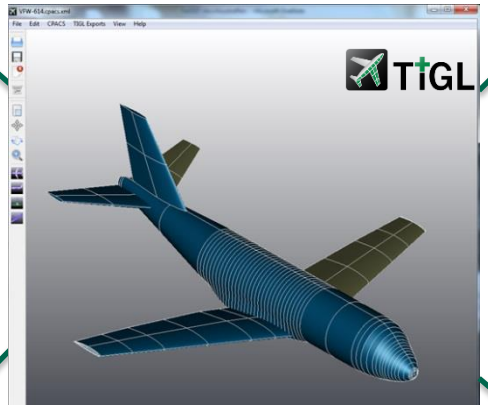
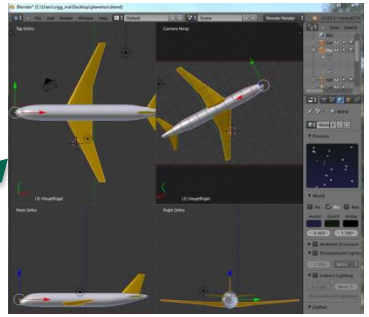
# Aircraft design at DLR

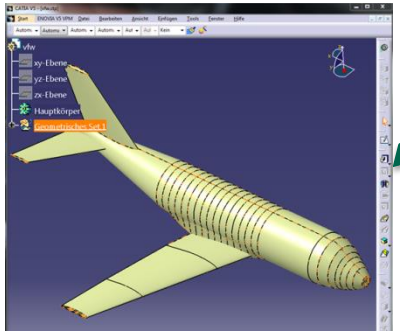


Aero/CFD Simulations



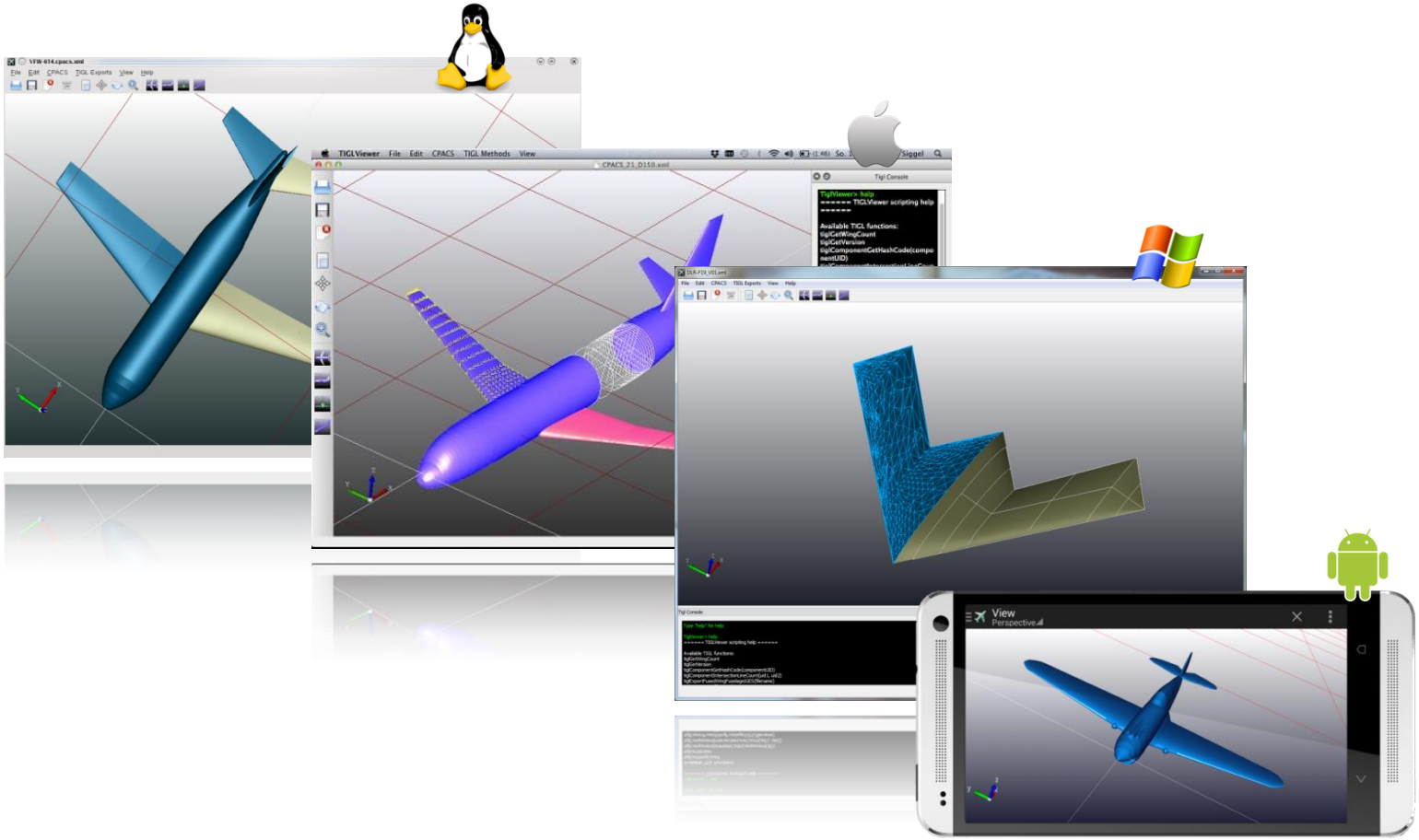
Rendering, Visualization



Modeling with CAD Systems

3D Printing

# The TiGL Geometry Viewer



# Why Android?

## Because we can!

*And it's fun ☺*


Hacking_

# What you‘ll need

- Android SDK
- Android Native Development Kit (NDK):
  - gcc cross compiler toolchains
  - ndk-build: The android build system for native code
  - ndk-gdb to debug native apps
  - Android specific libraries
- CMake / Autotools to cross-compile dependencies



# Steps to the Native Android App

1. Install Android SDK + NDK
2. Cross-Compile and patch 3rd party libraries with NDK toolchain
3. Define a Java Interface class for the communication with your native code
4. Write JNI glue code that calls native code and translates Java objects
5. Create a shared library containing your native code
6. Design Java based Android UI that talks to your JNI wrapper
7. Build the App: Compile native code + standard build steps

# Using 3rd party native libraries

- Many open source libraries are already adapted to be used as Android modules
  - Use these if available!!!
  - Can be found e.g. on https://github.com/android

- Or, port the library to Android and either
  a. Cross-compile using the default build system of the library (e.g. CMake, Autotools, Scons…) + create pre-built module
  b. Or, override build system with new Android.mk Makefile



# Cross-compiling CMake based 3rd party libs


1. Install standalone cross compiling toolchain

```
$NDK/build/tools/make-standalone-toolchain.sh --platform=android-9
 --install-dir=/opt/
```

2. Create AndroidToolchain.cmake

```
SET(CMAKE_SYSTEM_NAME Linux)
SET( TOOLCHAIN /opt/arm-linux-androideabi-4.6/)

SET( CMAKE_FIND_ROOT_PATH  ${TOOLCHAIN} )
SET( CMAKE_C_COMPILER    "${TOOLCHAIN}/bin/arm-linux-androideabi-gcc")
SET( CMAKE_CXX_COMPILER  "${TOOLCHAIN}/bin/arm-linux-androideabi-g++")

SET( CMAKE_FIND_ROOT_PATH_MODE_PROGRAM NEVER )
SET( CMAKE_FIND_ROOT_PATH_MODE_LIBRARY ONLY  )
SET( CMAKE_FIND_ROOT_PATH_MODE_INCLUDE ONLY  )
```

3. Configure CMake project with toolchain argument

```
cmake -DCMAKE_TOOLCHAIN_FILE=AndroidToolchain.cmake ...
```

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# Writing prebuilt module Android.mk

- The cross-compiled libs must be packaged as an Android module for further use

```
LOCAL_PATH := $(call my-dir)

include $(CLEAR_VARS)

# define module name and library #
LOCAL_MODULE := PTKernel
LOCAL_SRC_FILES := $(LOCAL_PATH)/obj/local/$(TARGET_ARCH_ABI)/libPTKernel.a

# set include directories #
LOCAL_EXPORT_C_INCLUDES := $(LOCAL_PATH)/include/oce

include $(PREBUILT_STATIC_LIBRARY)
```

- Copy Android.mk to root install directory of library



# Or - override build system with custom Android.mk

```
LOCAL_PATH := $(call my-dir)
include $(CLEAR_VARS)

# build TIXI_static library #
LOCAL_MODULE := TIXI_static

TIXI_INCLUDES := $(LOCAL_PATH)/src
LOCAL_C_INCLUDES := $(TIXI_INCLUDES)
LOCAL_EXPORT_C_INCLUDES := $(TIXI_INCLUDES)

# Add all *.c files from src directory #
FILE_LIST := $(wildcard $(LOCAL_PATH)/src/*.c)
LOCAL_SRC_FILES := $(FILE_LIST:$(LOCAL_PATH)/%=%)

# link with other Android modules #
LOCAL_STATIC_LIBRARIES := libxslt libxml2 curl

include $(BUILD_STATIC_LIBRARY)
$(call import-module,libxml2)
$(call import-module,libxslt)
$(call import-module,curl)
```

# Patching OpenCASCADE (and other 3rd parties) code

- Differences in Android's Bionic C library
  - No `timezone` function
  - No `pw_gecos` member in `passwd` struct
  - Missing System V IPC calls, i.e. provide workarounds to
    `shmat, shmget, semctl, semop, semget …`

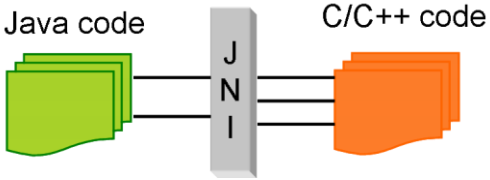
- Use `#ifdef __ANDROID__` for android specific code paths
- Deactivate X-Server based code paths

⟹ OpenCASCADE rendering engine must be replaced
(it uses X library calls, fixed function OpenGL pipeline …)



# Use JNI to wrap native code

- **J**ava **N**ative **I**nterface enables communication with native (C++) code
- Realized, by calling functions from a shared library (*.dll or *.so)
- Provides:
  - Loading shared library via `System.loadLibrary("mylib")`
  - Functions to convert between Java and C data types
  - Mechanism to call Java methods from C/C++




- BUT! - Java to C glue code has to be written by hand
- Header file of JNI Wrapper class should be created with `javah` (assures correct function names, including package names)



# JNI – write native interface (Java)

- Define interface class in Java

```
package de.dlr.sc.jnitutorial;

public class NativeInterface {
    static {
        // load tutorial-native.so from libs
        System.loadLibrary("tutorial-native");
    }

    // Declare a native methods
    public native void initNative();
    public native String getName();
    public native void setName(String s);
}
```

- Create JNI header file with javah

```
javah de.dlr.sc.jnitutorial.NativeInterface
```



# JNI – automatically generated header file

```
/* DO NOT EDIT THIS FILE - it is machine generated */
#include <jni.h>
/* Header for class de_dlr_sc_jnitutorial_NativeInterface */

#ifndef _Included_de_dlr_sc_jnitutorial_NativeInterface
#define _Included_de_dlr_sc_jnitutorial_NativeInterface
#ifdef __cplusplus
extern "C" {
#endif

JNIEXPORT void JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_initNative
  (JNIEnv *, jobject);

JNIEXPORT jstring JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_getName
  (JNIEnv *, jobject);

JNIEXPORT void JNICALL Java_de_dlr_sc_jnitutorial_NativeInterface_setName
  (JNIEnv *, jobject, jstring);

#ifdef __cplusplus
}
#endif
#endif
```

# JNI – handwritten C++ glue code

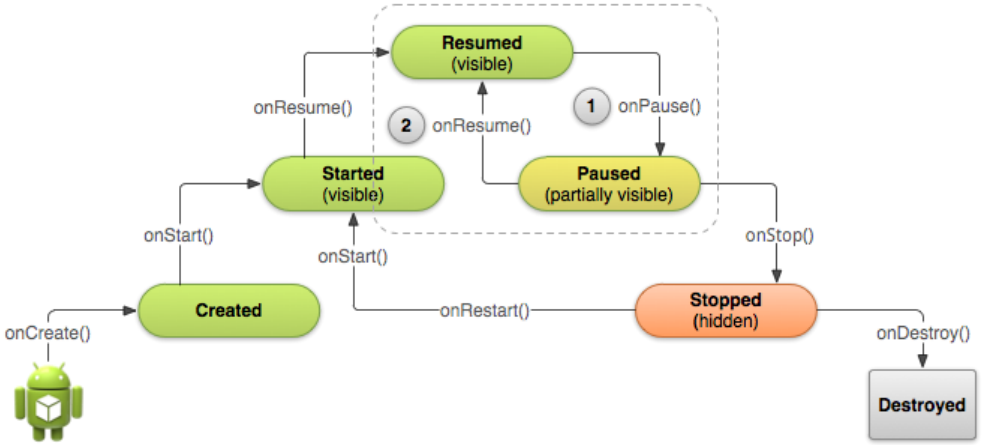
```
#include "de_dlr_sc_jnitutorial_NativeInterface.h"
#include "tutorial.h"

JNIEXPORT void JNICALL
Java_de_dlr_sc_jnitutorial_NativeInterface_initNative (JNIEnv *, jobject) {
    init_native();
}

JNIEXPORT jstring JNICALL
Java_de_dlr_sc_jnitutorial_NativeInterface_getName (JNIEnv * env, jobject) {
    // create java string from std::string
    return env->NewStringUTF(get_name().c_str());
}

JNIEXPORT void JNICALL
Java_de_dlr_sc_jnitutorial_NativeInterface_setName (JNIEnv * env, jobject, jstring name) {
    // convert to c-string
    const char * cname = env->GetStringUTFChars(name, NULL);
    // call library function
    set_name(cname);
    // free allocated memory for string
    env->ReleaseStringUTFChars(name, cname);
}
```

# Life cycle of native code

- With hybrid Java/C++ Apps, no automatic life cycle management for native code
- Compared to Java code, no need to store and restore state on suspend/resume

  Native library resides in memory

- Provide initialization and shutdown routines for native library



# Compiling + Packaging

# Automate build with Gradle and NDK

- Gradle?
  - The new build system for Android
  - Replaces Apache Ant
  - Used by Android Studio

- NDK integration into Gradle just recently added by Google
- Problem: Gradle creates Makefiles files which mostly don’t work
- Workaround:
  - Disable automatic creation of Android.mk Makefiles
  - Write your own Android.mk files
  - Define a custom build task to call ndk-build




# Automate build with Gradle and NDK

1. Register libs folder to the APK and disable automatic Android.mk creation

```
jniLibs.srcDir 'libs'
jni.srcDirs = []
```

2. Define custom task to build native code

```
task ndkBuild(type: Exec) {
  def ndkBuild;
  if (System.properties['os.name'].toLowerCase().contains('windows')) {
    ndkBuild = new File(System.env.ANDROID_NDK_HOME, 'ndk-build.cmd')
  } else {
    ndkBuild = new File(System.env.ANDROID_NDK_HOME, 'ndk-build')
  }
  commandLine ndkBuild, '-j', Runtime.runtime.availableProcessors()
}
```

3. Add task to build dependencies

```
tasks.withType(Compile) {
  compileTask -> compileTask.dependsOn ndkBuild
}
```

# Running + Testing

# Using the emulator efficiently

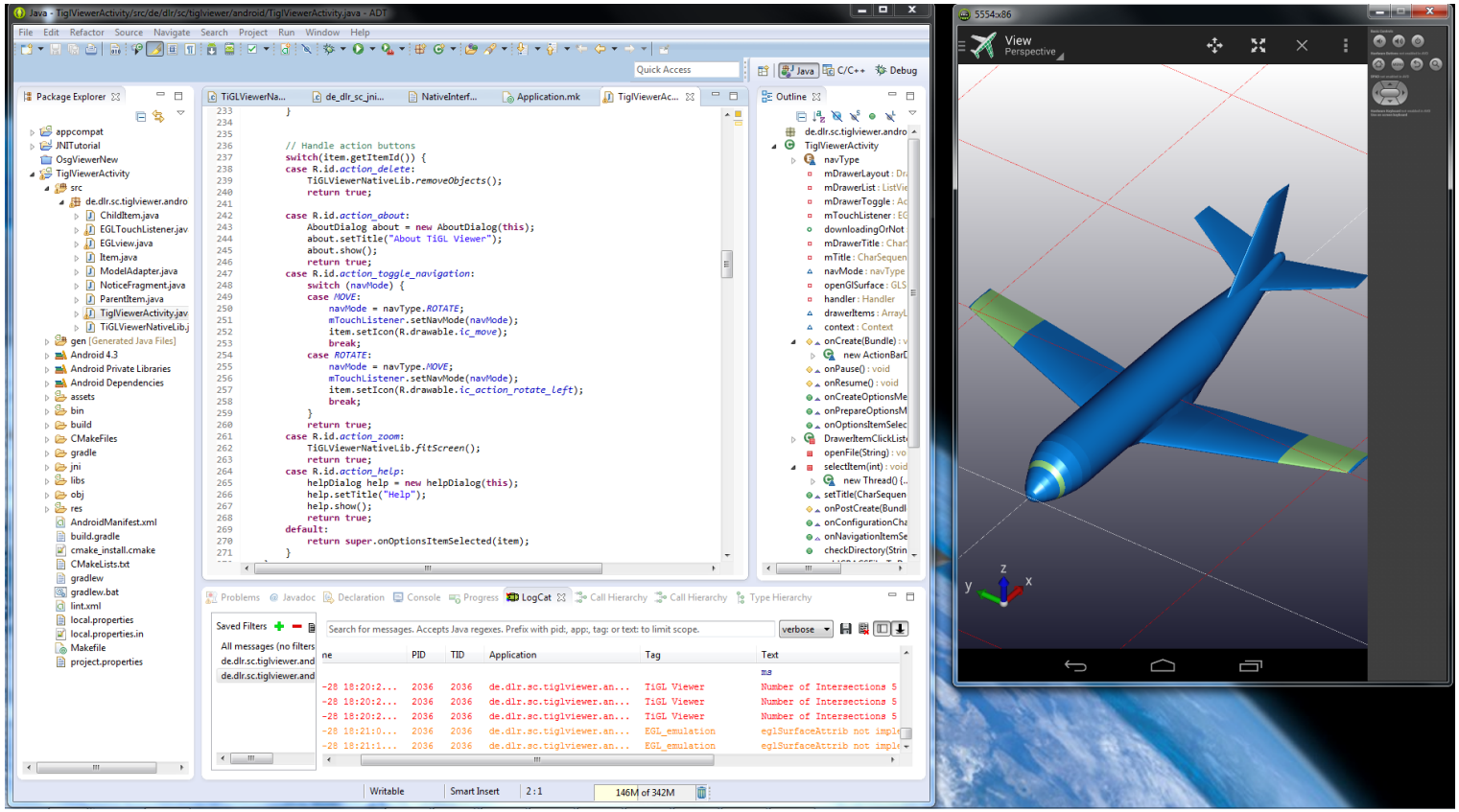
- Standard Android Virtual Device emulates ARM instructions using QEMU

so slow...

- Use a x86 based emulator with GPU acceleration
- Install Intel HAXM acceleration driver (part of Android SDK)
- All 3rd party libraries must be recompiled with an x86 based NDK toolchain
- Add `x86` to `APP_ABI` in `Application.mk` to compile for x86 platform



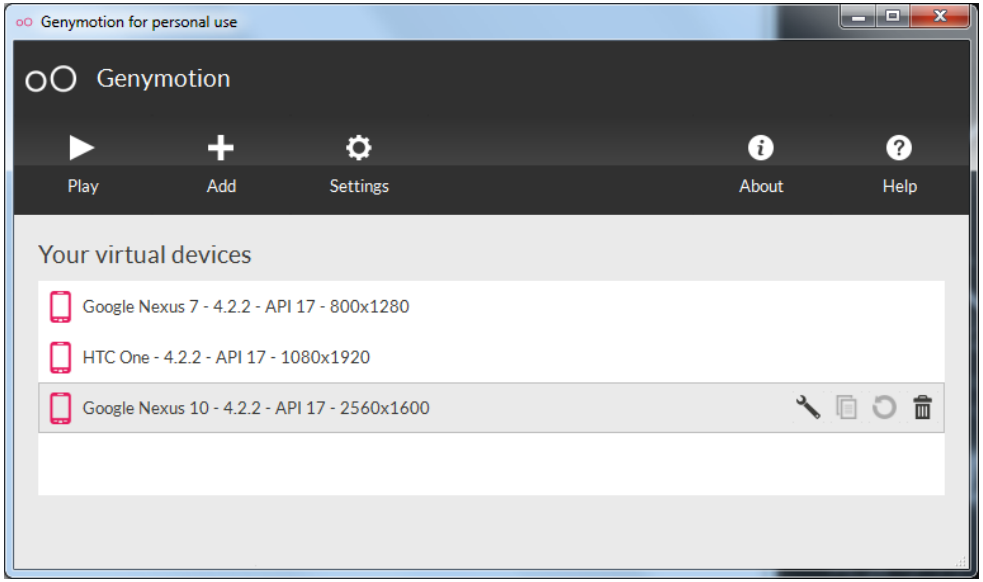
# Using the emulator efficiently

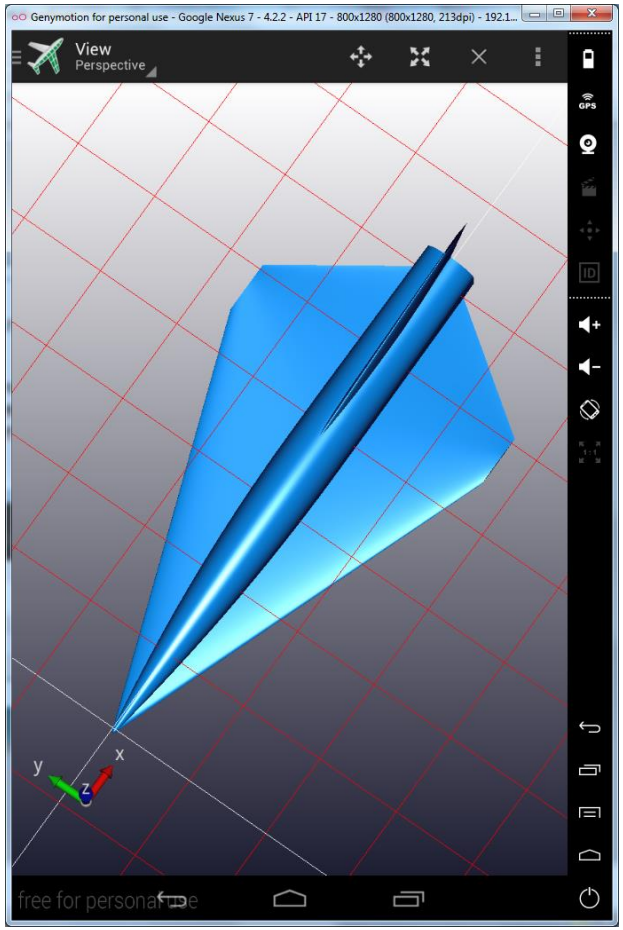


# The Genymotion Android emulator

GENYMOTION

- X86 based very fast Android emulator
- Uses VirtualBox under the hood
- Comes with many pre-configured devices
- Just works

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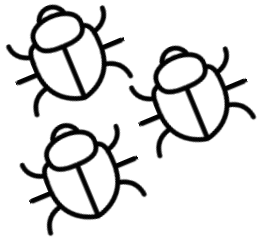
# Debugging native apps



- NDK ships debugger ndk-gdb

- Using ndk-gdb from Eclipse is tricky:
  - Set `APP_OPTIM := debug` in jni/Application.mk
  - Add `NDK_DEBUG=1` option to `ndk-build` command (IMPORTANT!)
  - Workaround an Eclipse Bug by running once

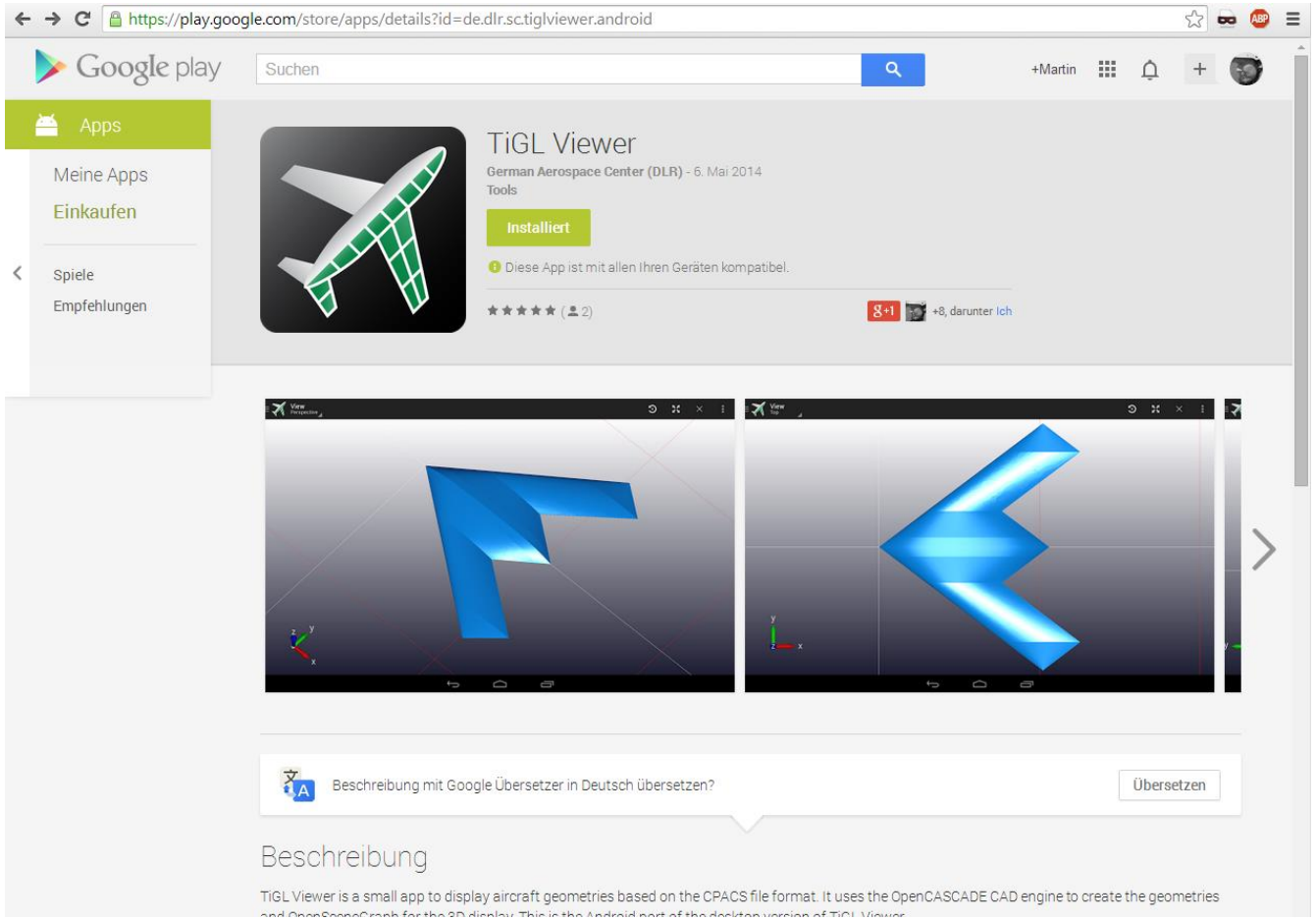
```
ndk-gdb --nowait
```

  from project directory while the app is already launched

- Note: Debugging with Genymotion Emulator needs a patch: http://stackoverflow.com/questions/22825388/cant-debug-native-android-apps-in-genymotion-via-eclipse



# TiGL Viewer in Play Store




# Questions

martin.siggel@dlr.de
https://github.com/rainman110/droidcon_jni

# OpenMP Thread parallelism on Android

- Apps crashing when using OpenMP directives outside the main thread
- Reason are differences in Thread Local Storage (TLS) on Android compared to Desktop
- BUT:
  - The NDK can be patched, to enable OpenMP:

http://recursify.com/blog/2013/08/09/openmp-on-android-tls-workaround